NOISE LEVELS AND USEABLE RECEIVER SENSITIVITY

Chuck Hutton

A recent article in DX News "Atmospheric and Galactic Noise in the BCB" touches on a subject of great interest to BCB DX'ers-just exactly how much receiver sensitivity is really necessary? Based on several very useful references, the conclusion drawn is that sensitivity of the kind found in most modern receivers is not required for listening on the MW band. This is correct, however ....

Noise affecting receiver sensitivity can be divided into: (1) thermal noise of the antenna, produced by the antenna being - warm piece of metal relative to absolute zero. This noise is wideband and therefore constant across the passband of the receiver. Its value is represented by:

$$P_{(\text{thermal noise})} = kT_oB$$

with: k = Boltzman's constant, 1.38×10^{-23}
T_0 = temperature in degrees Kelvin, or $^oC+270$
B = receiver bandpass in Hertz

We will assume 2.1 kHz as this is an industry standard as a result of its being an almost universal bandpass for single sideband reception at HF and also being ideal for international DX. These parameters yield a P_n of 8.4×10^{-18} watts, an important figure as values for many other kinds of noise are referenced to this value.This is equivalent to .04 uv into a 50 ohm antenna input. Obviously this particular noise voltage can not be an important figure in receiver signal plus noise to noise ratio unless atmospheric noise and electrical noise are at very low values. (2) thermal noise of the receiver, produced by a combination of thermal noise in resistors and coils plus noise produced by the active devices (shot noise, partition noise, etc.). The amount of noise is generally represented by the term noise figure, which is merely the log of the input signal to noise ratio divided by the output signal to noise ratio. Typical NF's for modern HF receivers vary from 5-15 dB. This translates roughly into a receiver generated noise power of between 2.6×10^{-17} and 2.6×10^{-16}. Slightly older receivers such as the Collins and Hammarlunds with sensitivities of a few microvolts have noise figures of about 30 dB, or a noise power of 8.4×10^{-15}. Converting noise power to an equivalent noise at the receiver input, we see that a 5 dB NF receiver sees .07 uv and a 30 dB receiver sees 1.3 uv. (3) Galactic or cosmic noise bombards the ionosphere from the sun and outer space. As seen from the CCIR reference, the level is significant. However, these values do not take into account the fact that cosmic noise will not pass through the ionosphere at MW frequencies, with rare exception. Therefore, very little of this noise will arrive at your antenna. The CCIR report specifically states that ionospheric shielding was not taken into account. The fact that values are shown at all for MW frequencies is due to the fact that values were extrapolated from those for higher frequencies, where penetration does indeed occur. Cosmic noise can generally be discounted below 15 mHz; on the 21 mHz ham band galactic noise can on rare occasions be the largest signgle source of noise. On the 28 mHz it is somewhat often the main source of noise. (4) atmospheric noise is one of the two great enemies of MW DX'ers. Reference to the CCIR report shows that the least value for F_{am} (an averaged value of atmospheric noise) would be 49 dB, arrived at by choosing the 1600-2000 hour period for winter at a frequency of 1.5 mHz. (Charts for daytime reception were ignored) As F_{am} is defined as dB above antenna thermal noise, we have a P_{atmo} of 6.7×10^{-13} watts, or 11.5 uv of noise present across the antenna, right? Well, almost .... First of all, the CCIR values for atmospheric noise are given for a 1 kHz bandpass. To convert to our 2.1 kHz standard, we need to add the correction factor of 3.2 dB to the chart values. Also, we might wish to consider just how constant these values of noise are. Once again our friends at CCIR have given ut what we need: the values for D_u and D_l on the chart that accompanies each contour graph. D_u is the ratio (in dB) of the noise power that is exceeded only 10% of the time to F_{am}. D_l is the ratio (in dB) of the noise power that is exceeded 90% of the time to F_{am}. Flipping through the set of graphs, we see that D_u and D_l will vary from about 8 to 20 dB. This means that 10% of the time, we will encounter noise values between around 6 to 100 times greater or lesser than the average value for that period! If you

care to use other parameters than the lower and upper 10% figures, there is also a chart of the standard deviation for each time period. Let us now calculate the signal necessary for a 10 dB S+N/N ratio, assuming that we are DX'ing during the 1600-2000 hour period of winter at a frequency of 1.5 mHz, and also that we have defied Murphy and are listening during one of those periods when the noise is at the D_1 level-the value exceeded 90% of the time. The chart says this value is 38 dB (11 dB below the average value); we add our 3.2 dB bandpass correction figure and obtain a result of 41.2 dB over kT_oB, or 1.1 X 10^{-13} watts. For our 10 dB S+N/N ratio, we need S+N/N = 10, or 9N=S. Since N is 1.1 X 10^{-13}, the signal required is 9.9 X 10^{-13}, or 14 uv. This is an absolute best case analysis for we have assumed a low noise at the top end of the BCB and have neglected electrical noise and certain types of receiver generated noise. For comparison, let us also look at the D_u level for noise at .5 mHz during the summer 0000-0400 period. Since D_u is 107 dB plus the 3.2 dB correction factor, noise power is 8.8 X 10^{-7} watts, or a mind boggling 13,263 uv (13.263 mv), requiring only a modest 39,769 uv for a 10 dB S+N/N ratio.... These are the times at which noise can be heard underneath semi-locals and it is impossible to DX, unless you are enamoured of tracking thunderstorms..... (5) So you think you've read the bad news and it's going to get better? Unfortunately, we have electrical noise to contend with also. Here, things become a little less concrete. Values depend on just whom you wish to believe. The table below presents a handful.

		Urban	Rural
Johnson, 73, Jan. 67	500 kHz	38965 uv	6949 uv
	1 mHz	23162 uv	3474 uv
	1.5 mHz	12901 uv	1223 uv
CCIR Report	500 kHz		48599 uv
	1 mHz		38965 uv
	1.5 mHz		12929 uv
Nelson	1 mHz	600 uv	85 uv

Some of the above seem to be incredible figures, in addition to being widely varying. Whatever the truth may be, it is certain that electrical noise must be considerably above all other sources of noise unless you happen to be miles from a large city and away from power lines.

A source of noise that really doesn't classify as noise in a strict sense is the distortion products radiated by transmitters and generated in receivers. Contributors include second and third order intermodulation, receiver reciprocal mixing, and other forms of distortion brought on by overmodulation and overdriving. These values are impossible to predict, but an absolute minimum of a few microvolts exists simply due to the third order intermodulation distortion floor of the receiver. If you are using an amplified loop or Beverage in a high signal strength urban area and an average receiver, transmitter originated slop plus receiver distortion can easily be hundreds or thousands of microvolts. Whatever the case, said distortion products will exceed in level the specified receiver sensitivity value.

Obviously no firm figure can be given for the required sensitivity of a MW receiver. The required value will depend on time of day, season of the year, frequency, geographical location, proximity to local noise sources, and the strong signal handling capabilities of your receiver. It is improbable that you will ever need sensitivity below 20 uv. This is confirmed when you think of the radios used during the 20's and 30's to receive low power Europeans and Australians. Also think

of receivers like the Collins R388/URR which is specified at 15 uv sensitivity on part of the BCB. For years I used this receiver, logging 120 TA's and hearing as far west as the Gilbert and Ellice Islands. One can create "poor" sensitivity by the use of resistive attenuators ahead of the RF stage; it is easy to demonstrate that the same weak signals can be heard with drastically reduced sensitivity.

Now, if all this modern sensitivity is not needed, you might wonder why your receiver has an RF stage. The answers are many: (1) AVC is traditionally applied to the RF stage in order to help improve the strong signal handling of stages further down the line, (2) adding an RF stage increases the number of tuned circuits ahead of the mixer, reducing the number of strong, unwanted signals that the mixer must contend with, (3) most manufacturers of high frequency general coverage receivers do not care much about sophisticated reception on the lower frequencies. Since receiver sensitivity and noise figure become all important up around 15 or 20 mHz, RF stages are needed for our general coverage receiver. The BCB DX'er must therefore pay the price of poor strong signal handling. Recently, some factors have come into play which change the picture somewhat: (1) PIN diodes have been developed and function well as input attenuators. They are rapidly becoming common in sophisticated, high performance HF receivers. This is an alternative to AVC on the RF stage, and a better alternative at that, because the old system of applying a bias voltage to the grid (AVC) or cathode (garden variety RF gain control pot) changes the operating point of the tube and restricts dynamic range. (2) tuned circuits suppress unwanted signals. However, the amount of selectivity ahead of a mixer in the usual circuit is not sufficient to protect the mixer from extremely strong signals near in frequency to a wanted, weak signal. Our real selectivity is in the crystal or mechanical filter in the IF stage, and by this point the damage is done. The usual culprit in poor strong signal handling is the stage immediately infront of the filter, as at that point the signals are strongest. Stages all the way back to the RF are also contributing to the problem. Ideally, what we need is either lower gain ahead of the mixer or a better mouse trap for the mixer. Regarding the first, different gain distributions have been tried by different manufacturers, with results ranging from very poor to good. Very poor is typified by receivers such as the Heath HW101 or the Yaesu FT101. Entirely too much of the gain is ahead of the main receiver selectivity, to the detriment of the mixer strong signal handling. On the other end of the extreme is the Collins R390A. Looking at the stated sensitivity of 2 uv and noting that it has many stages of gain using high transconductance tubes ahead of the filtering, you might think that gain is being wasted in view of the rather low sensitivity by modern standards. This is the result of the inclusion of the extremely high Q, mechanically tracked coils (which provide unusually high input selectivity), the rather high losses of the coils and transformers, and the fact that gain stages are not run at maximum possible gain. In this manner gain is held down to a rather low level in front of the filters, and selectivity ahead of the filters is very high as compared with other HF receivers. Using third order intermodulation distortion as a guide to strong signal handling, compare the R390A and the Yaesu FT101: -4 dBm versus -21.5 dBm, a decided large advantage in favor of the 390A. By the way, the FT101 was chosen because it is typical of the modern day FET fron end, sensitivity below .5 uv, receiver. Its mixer is also fairly typical. Popular general coverage receivers such as the FRG7 will fall into the same general category. Older vacuum tube receivers (particularly the single conversion models) will perform only slightly better. My favorite of all is the ancient HQ129X, as it is single conversion and uses old low gain metal tubes throughout the RF and IF. Good for MW, lousy for most everything else.(3) so manufacturers include RF stages to help sensitivity on the higher frequencies... There really wasn't much choice in the past. However, advances of recent will allow us to kill two birds with one stone, namely strong signal handling and getting rid of the RF stage that we don't need, as it turns out. The gem of modern technology making this possible is the double balanced Schottky diode balanced mixer. Used in a bridge arrangement and designed properly, such mixers will provide a third order intermodulation distortion level of around +30 dBm if presented with 50 ohm resistive terminations at all frequencies and are supplied with the correct level of oscillator injection. Performance such as this will allow us to handle the strongest signal that is likely to be encountered on the BCB without having the receiver break out in crossmodulation, intermodulation distortion, blocking, and gain compression. On the other hand, we need to consider how these mixers will handle the lowest signal levels of interest on the BCB. With insertion losses of between 5 and 10 dB, and with no RF stage, it is currently possible to build a receiver with less than a 10 dB noise figure. This is far below what we

need on the BCB, insuring that we can design BCB receivers with no RF stage and a passive, conversion loss (most mixers have a modest amount of conversion gain) mixer stage. Several receivers of this gender have been featured in ham radio magazines of recent, and as the advantages of this type of circuitry have become apparent to the listener frustrated by poor receiver strong signal handling, double balanced diode mixers with no RF stage infront of them have become the state of the art for high performance receivers. At this point, this is now only just becoming the practise for receiver designers at commercial manufacturers. RACAL has been manufacturing a high-priced receiver (RA1772 and the 6700 series) for a few years now that feature mixers producing excellent strong signal properties. Atlas followed suit with the 180/210, but unfortunately poor design of the IF termination network degraded performance to a point that it could only match the best active mixer receivers like the 390A. A few recent entries to the market are head and shoulders above the rest. Two are of interest: (1) the Rohde and Schwartz HF1030, a digitally programmable receiver with performance equal to or better than anything now being made. Price-$4300. It is doubtful that many of these will turn up in the hands of hobbyists, hi. (2) the new Drake R7, the companion to the T7 and essentially what is contained in the transceiver model TR7. Specs are excellent in regards to mixer performance, and everything else for that matter. The oscillator is a synthesized phase locked loop type. Price is rumored to be in the vicinity of $1000 but Drake has not released anything other than technical specs so far, or indicated a release date other than the now impossible end of 1978. This receiver sure looks like a winner and could easily be the top BCB receiver short of expensive models designed for professional use.

It might be of interest to note that prices for diode double balanced mixers are quite reasonable. Exact prices will depend on whether you wish to purchase a low, high, or very high level type, and whether you want cheap PC board connections or expensive BNC connectors. Rock bottom is around $8, with some models running upwards of $50. The ever-popular Mini-Circuits SRA-1 sells for $7.95 and will be acceptable for most BCB receivers. Others such as Anzac and Relcom manufacture similar units.

Bryan Radio Station To Plug Into Solar Power Experiment

By STEVE POLLICK
Blade Regional Bureau

BRYAN, O. — If all goes well, WBNO-AM radio here might as well become WSUN, for it is going to plug into solar power Aug. 29.

An array of current-producing photovoltaic cells covering a third of an acre will convert sun power into the 4,000 watts of power needed for the station's transmitter, which broadcasts a 500-watt signal from sunrise until signoff at sunset daily.

"WBNO, 1520 AM, We're Sun-Sational! Solar-Powered," a promotional message says on potholders readied for handing out on the day of the big switch.

The station was selected by the U.S. Department of Energy from among some 500 small, daytime AM stations across the country to participate in a demonstration project, Luke Thaman, WBNO's general manager, said.

The idea behind the project, which is being carried out under contract by the Lincoln Laboratory of the Massachusetts Institute of Technology, is to determine the practicality of a small solar-power system that would be usable in a variety of applications with little modification, and yet be economically attractive in the mid to late 1980s.

Ideal For Demonstration

WBNO was chosen last fall, Mr. Thaman said, explaining that a small radio station was considered ideal for demonstration of such a system because it has a predictable, daily power load.

The station also met another requirement: it had the space in its rural Bryan setting for the array of photocells.

Monitoring of the operation will seek answers to such questions as whether the photocells will function efficiently when covered with a film of dust or dirt from the weather, and whether the extremes of temperature will seriously hamper operations.

The general manager, who has been to the MIT lab twice in preparing for the installation, said that MIT personnel will be working closely with the station throughout the operation.

Mr. Thaman is not sure how much the Government has spent to date on the project. But he points out that each of the 800 modules of photocells cost $300, meaning an investment approaching $250,000 just for the array.

A computer system will operate the array, which will produce 15,000 watts of power at high noon on a clear day, far more than needed to power the transmitter. Excess power will be used to operate the control rooms of WBNO-AM and FM, and will charge 4 huge storage batteries having a total of 60 cells.

Power On Cloudy Days

The array will be able to produce some power even on cloudy days, Mr. Thaman said. He said that a small bank of photocells set up at the station will light a lightbulb in the station offices even on overcast days.

Over a year's time, the array is expected to handle 85 per cent of the transmitter's power requirements.

Iran radio will restrict use of music

TEHRAN, Iran (UPI) — The chief of national Iranian radio and television announced his network will restrict music broadcasts to revolutionary songs and marches during the Moslem month of Ramadan starting today.

Ayatollah Khomeini Monday called for the elimination of music broadcasts because he considered music a narcotic drug and "treacherous."

The newspaper *Kayhan* Tuesday quoted the broadcast executive as saying music broadcasts would be restricted only during Ramadan. Sources said music broadcasts were to be banned beginning Monday, but the order was postponed until today.

Radio Iran Tuesday broadcast pieces of Western classical music, Persian folk songs and military marches.